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FOR ASTRONOMICAL MIRRORS

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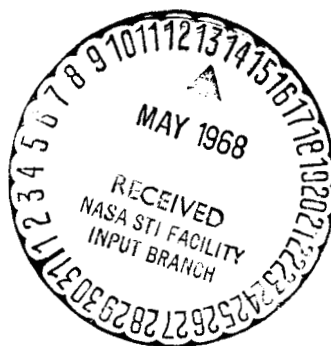
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THE CORROSION RESISTANCE OF CERTAIN METALLIC MATERIALS FOR ASTRONOMICAL MIRRORS

Zh. M. Loretsyan

ABSTRACT. Experimental study of the corrosion resistance of the aluminum-magnesium alloy AMg6L with chromium or nickel coatings, as well as bronze and 3Kh13 steel used in fabricating astronomical mirrors. The metals were tested under special laboratory conditions simulating the corrosive effects of the ambient atmosphere and certain chemical solutions on astronomical mirrors. A chromium-film surface is shown to be most suitable as the protective coating. The bronze and AMg6L alloy mirrors are shown to have poor corrosion resistance.

A cycle of chemical tests was performed to investigate the possibility of using mirrors made of an aluminum-magnesium alloy with chromium and nickel coatings in the construction of astronomical instruments. Conditions imitating the corrosion influence of the ambient atmosphere and of special chemical solutions on astronomical mirrors were created artificially in the laboratory. /58¹

The investigation of the corrosion resistance of alloy AMg6L, the chromium and nickel coatings on these alloys, and also mirror bronze in comparison with steel 3Kh13 which is being used at the present time in the manufacture of the 720 mm mirror at Pukhovskaya Observatory, were conducted in various media. The corrosive media used were the following solutions:

1. A 3% solution of common salt, imitating the influence of wet marine air on metallic mirrors.
2. A solution of hydrochloric acid at concentration pH = 2.6, imitating the influence of the acidity of the air on metallic mirrors.
3. Solutions of NaOH at 10 and 20% concentrations, used to remove the aluminum layer which is applied to astronomical mirrors in order to increase the reflective capacity. A very thin layer of pure aluminum is applied to the polished mirror surface in a vacuum. The aluminum layers have very high stability and mechanical strength, but with time they grow dull, lose their high reflective capacity and are sometimes broken. Therefore, the necessity arises of removing the old aluminum layer for repeated alumination. The classical method of removing the aluminum layer is to dissolve it in an alkaline medium. In order to remove "fresh," i.e. recently applied layers, a 20% solution is generally used, while "old" layers are removed with a 10% /59

¹ Numbers in the margin indicate pagination in the foreign text.

solution of alkali. On the basis of this, tests were performed with two concentrations of caustic soda solution. The tests were performed on parts 60 mm in diameter, 11-12 mm thick, with the reflecting surface ground and polished flat. The test duration was 24 hours. The evaluation of the corrosion resistance of the mirrors was performed visually and, furthermore, before and after the tests the mirror surface was photographed using the "Neofot" universal Zeiss microscope at 10 power magnification.

The results of the tests are shown in Table 1.

In order to determine the influence of corrosion on the quality of the polished optical surface of the specimens tested, their reflective capacity was determined before and after the chemical tests. Determination of the reflective capacity of the surfaces was performed using a special installation, an optical diagram of which is shown on Figure 1.

The operating principle is as follows. Monochromatic radiation from a monochromator, after passing through quartz plate (2), was reflected from the surface of quartz plate (3) and struck photo element (4). The radiant energy recorded on the photo element was read off on the scale of galvanometer (5). In order to determine the reflective capacity of the surface of the test specimen (6), plate (3) was rotated to position II, while plate (2) was removed from the optical system. After this was done, the light beam from the monochromator, after passing through plate (3) and being reflected from the surface of the specimen (6) and the surface of plate (3), struck photo element (4). Taking the indication of the galvanometer produced in the first variant as 100% of the light flux, the reading taken after the specimen had been placed in the system, expressed as a percent, determined the reflecting capacity (reflection coefficient ρ) of the specimen surface. In order to equalize the optical length of the path of both systems, in the first case plate (2), identical to plate (3), was placed in the monochromator. The reflecting capacity of the surface of the specimens being investigated was determined for three light wavelengths:

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$$\lambda_1 = 458 \text{ m}\mu; \lambda_2 = 550 \text{ m}\mu; \lambda_3 = 660 \text{ m}\mu.$$

The optical system shown on Figure 1 determined only the approximate value of the reflection coefficient, but this is quite sufficient for comparative characterization of the corrosion stability of the metal specimens being tested.

The values of reflection coefficient produced are shown on Table 2.

The results of these tests showed that of all the materials tested, the most highly corrosion resistant is an electrolytic chromium layer on an aluminum-magnesium base. However, if there are pores in the coating, solutions of alkali or acid, penetrating through the pores to the AMg6L alloy, react with it and thus decrease the adhesion of the film to the base, causing the chromium to be raised around the edges of the pores. The reflecting capacity

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TABLE 1

Material	Solution		
	3% NaCl	HCl, pH = 2.6	20% NaOH
3 Kh13 steel	several brown corrosion points	no corrosion	10% NaOH
AMg6L alloy	many corrosion points	surface dull	no corrosion
mirror bronze	no corrosion	surface color became pale brown	Alloy dissolves rapidly. Surface at this point lower than general level, rough. Color of surface became dark brown, surface structure visible.
chromium coating	no corrosion	No corrosion.	Edges of pores raised..
nickel coating	no corrosion	Surface dull. Edges of pores raised.	No corrosion. Edges of pores raised.

of the chromed surface did not change under the influence of chemical solutions. A nickel film applied chemically also is rather stable to the corrosive media used. However, the action of dilute hydrochloric acid causes the mirror surface to become dull; the surface does not polish up when rubbed with a flannel cloth. Pores on the nickel coating, when attacked by acid or alkali, caused the same negative results as did pores in the chromium coating. The reflecting capacity of the nickelized surface was decreased by 1.7-1.8 times when an acid solution acted on the surface. The 3Kh13 steel mirror is corrosion resistant. However, certain sectors of the mirror had corrosion dots resulting from the presence of slag inclusions or impoverishment of this sector in chromium. The reflecting capacity of the steel surface remains generally unchanged under the influence of the solutions used. Mirror bronze is not very stable to corrosion in alkali and acid solutions; the mirror surface becomes darker in both solutions. When the acid solution acts on the surface of mirror bronze, the reflecting capacity is decreased by an average of two times, and the corrosion of the surface resulting from the action of 20% NaOH actually makes the reflection of light rays from the surface impossible. AMg6L alloy reacts strongly with alkali solutions and relatively weakly with acid. Complete absence of reflecting capacity of the corroded surface was noted. /63

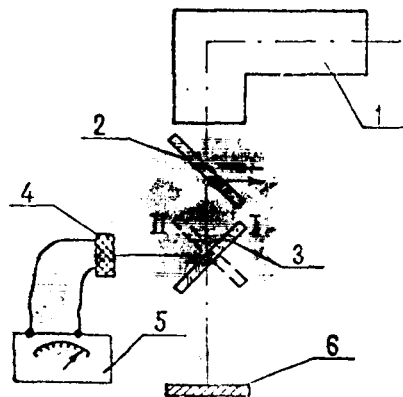


Figure 1. Device for Testing Reflecting Capacity

The results of these experiments have allowed us to determine that the most suitable of the materials tested for the manufacture of astronomical mirrors, from the standpoint of corrosion resistance, is a chromium coating on AMg6L alloy. The nickel-phosphate coating may also be used, but only when the surrounding air has low acid content. However, pores are not permissible either on the chrome or nickel surfaces. It should be noted that when the working surface of an AMg6L alloy mirror with a chromium or nickel coating is dealuminated, the remaining portion of the mirror should be carefully protected from the action of the alkali. A 3Kh13 steel mirror is stable to corrosion, but foreign inclusions and the presence of sectors impoverished in chrome can cause corrosion of the working surface. Bronze mirrors are unsatisfactory

from a corrosion standpoint, which was the reason for the rapid darkening of astronomical mirrors made of this alloy in the past. Mirrors made of AMg6L aluminum-magnesium alloy are completely unacceptable without the usage of coatings.

It should be noted in conclusion that the experiments were performed by us with the cooperation of Senior Engineer G. G. Lavrent'yeva.

TABLE 2. REFLECTION COEFFICIENT ρ , %

Material	λ, μ	Before exper- iment	Solution			
			3% NaCl	HCl pH 2.6	20% NaOH	10% NaOH
3Kh13 steel	458	52	52	52	52	52
	550	54	54	54	54	54
	660	57	57	57	57	47
mirror bronze	458	56	56	20	0	4
	550	60	60	30	0.75	4.75
	660	67	67	41	1	6.2
electrochemical chrome coating	458	58	58	58	58	58
	550	62.5	62.5	62.5	62.5	62.5
	660	66	66	66	66	66
nickel-phosphate coating	458	44	44	24	42	42
	550	49.5	49.5	49	48.5	48.5
	660	55.5	55.5	32.5	54	54
AMg6L alloy	458	18	11	0	0	0
	550	22.5	12.5	1.5	0	0
	660	26	14.5	2	0	0

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